Measuring Nuclear Effects with MINERνA

APS April Meeting 2011

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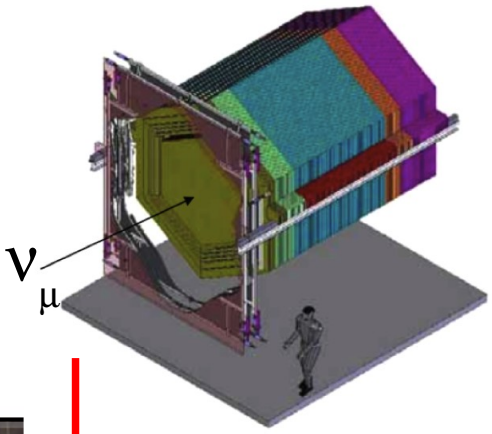
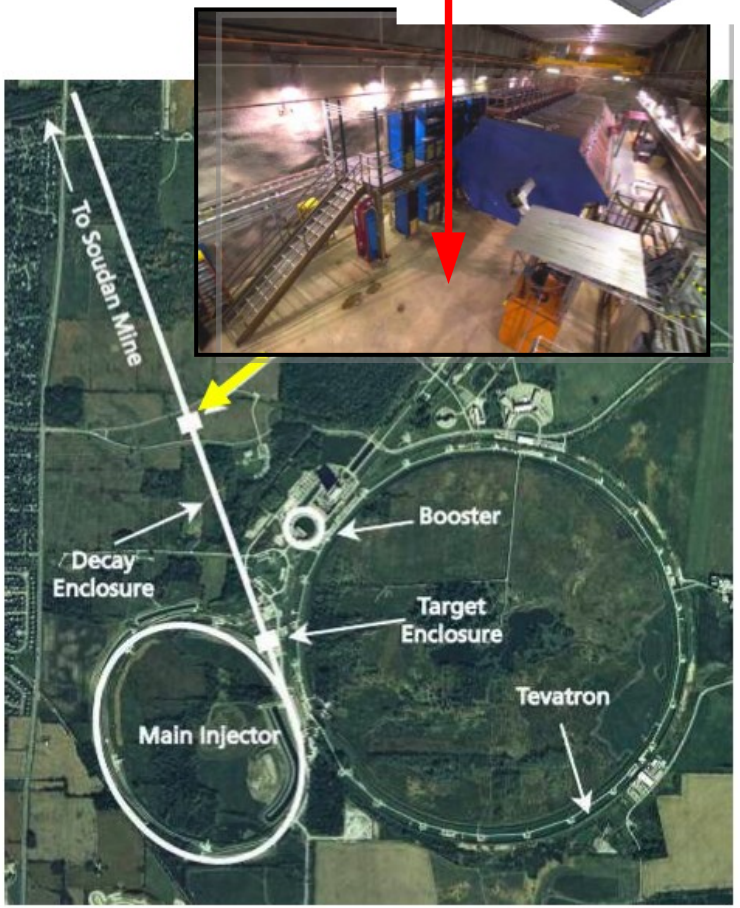
On behalf of the MINERνA collaboration

MINERνA
(Main INjector ExpeRiment ν-A)



- Neutrino scattering experiment in the 1-20 GeV energy range.
- Uses NuMI neutrino beamline at Fermilab.
- Located in front of MINOS near detector.
- Uses MINOS near detector as muon spectrometer.



Fermilab, Batavia IL, USA

NuMI Beam

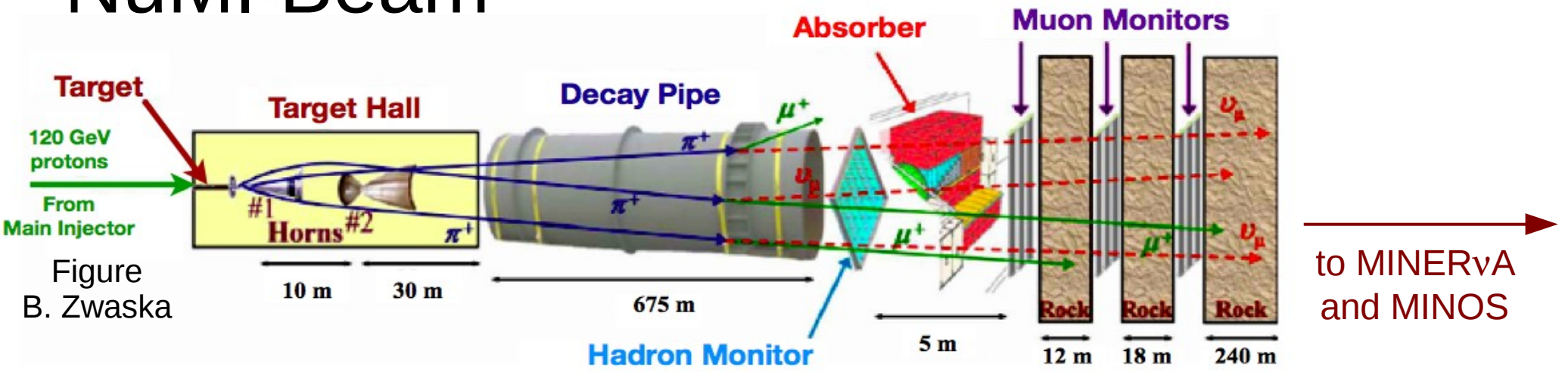
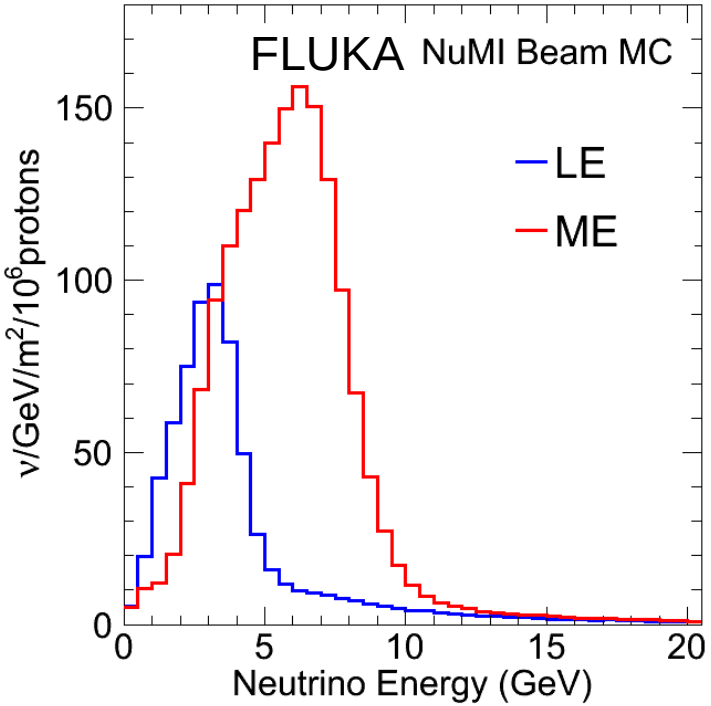
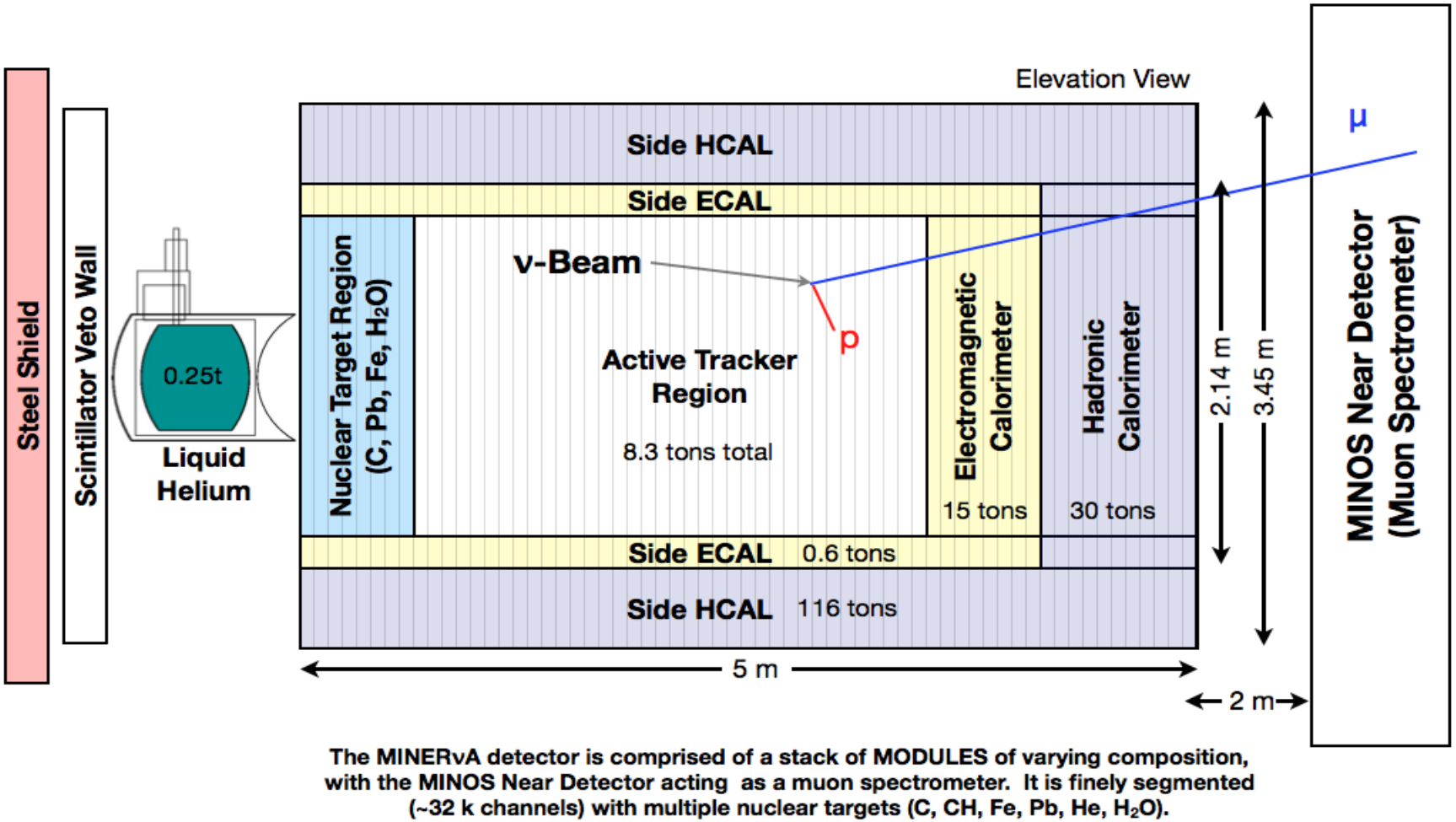


Figure
B. Zwaska



- Very intense neutrino beam with a power of 300 – 350 kW and ~35e12 P.O.T. (Protons On Target) per spill.
  - Spill: 10 μs duration at ~0.5 Hz frequency.
- Energy distribution can be tuned by changing position of target with respect to horns.
- Anti-neutrino beam is obtained by reversing the current in the magnetic horns to focus π^- instead of π^+.

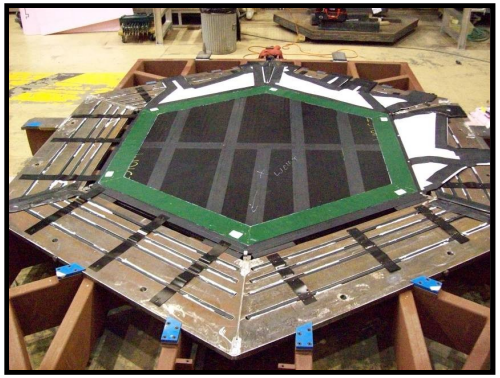
MINERνA Detector Layout



The MINERνA detector is comprised of a stack of MODULES of varying composition, with the MINOS Near Detector acting as a muon spectrometer. It is finely segmented (~32 k channels) with multiple nuclear targets (C, CH, Fe, Pb, He, H_2O).

120 modules of 4 types: nuclear targets, tracker, ECal and HCal.

MINERνA Modules



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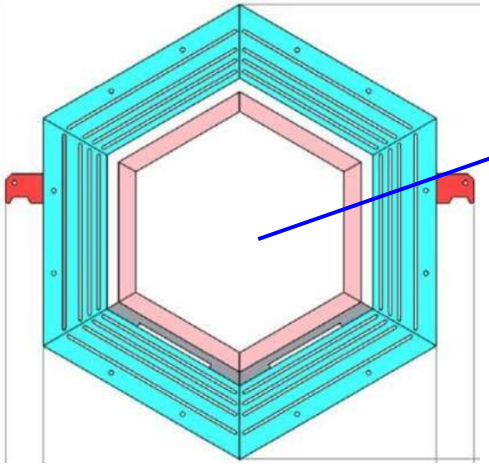
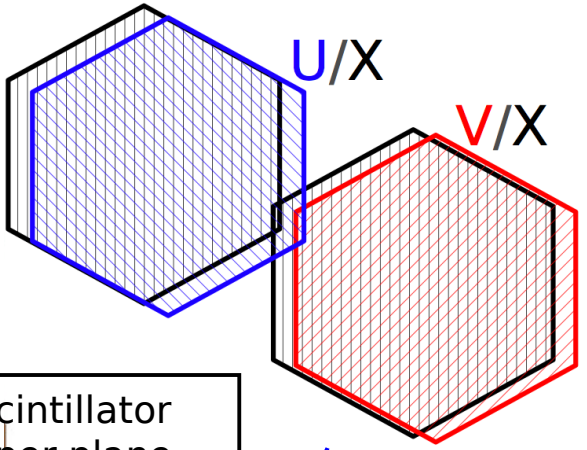
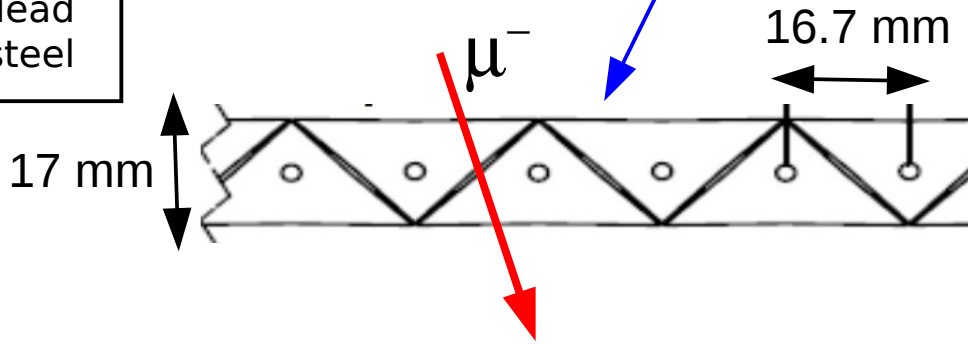
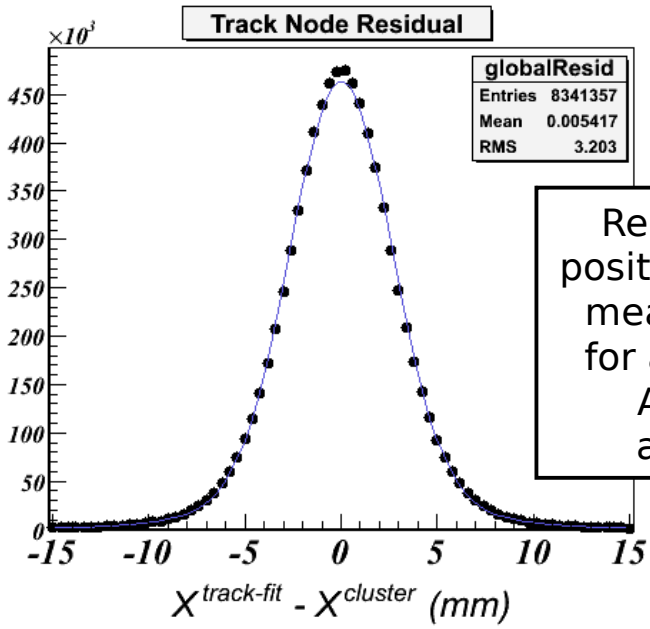




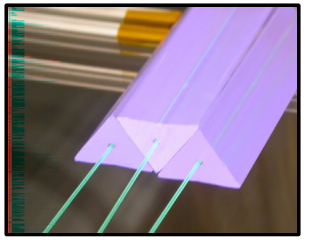
127 scintillator strips per plane.

Tracker module = 2 planes
ECAL module = 2 planes + 2 (2 mm thick) sheet of lead
HCAL module = 1 plane + 1 (1 inch thick) sheet of steel





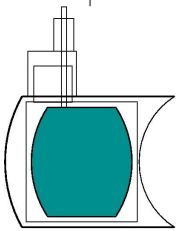
Residual between a fitted position along a track and the measurement in that plane for a sample of rock muons AFTER applying plane alignment corrections

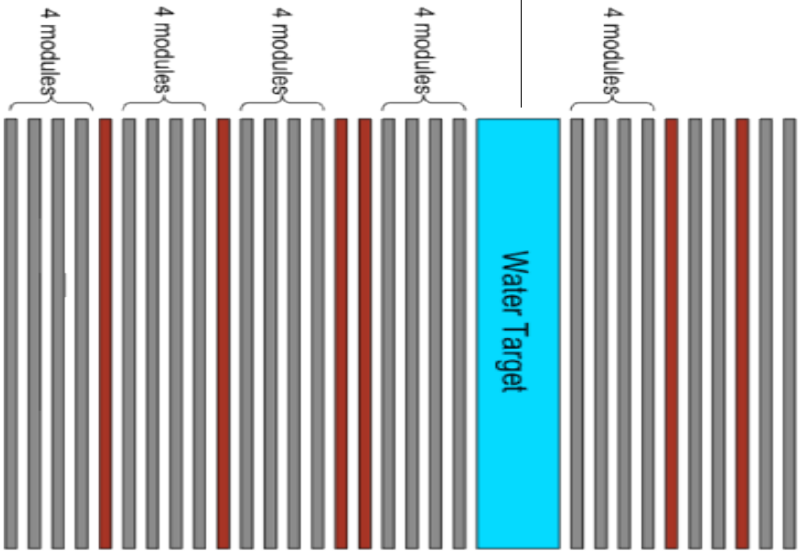


Triangular strip to allow charge sharing

MINERνA Nuclear Targets

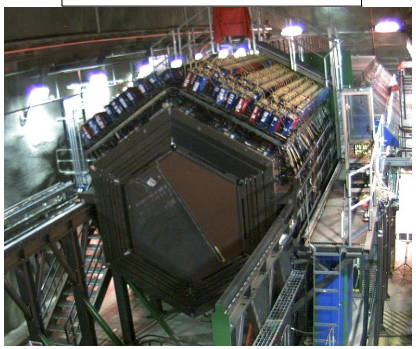
Liquid Helium





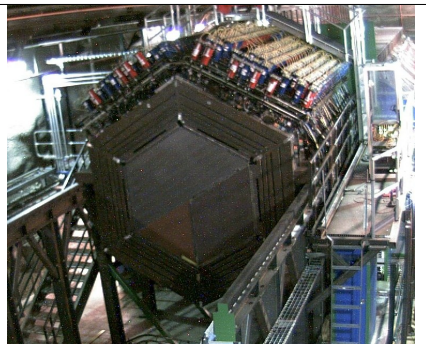
Prototype Water Target

Iron / Lead

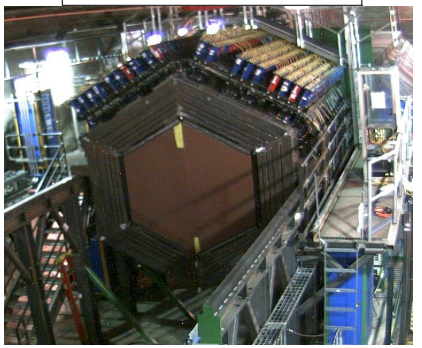


Lead / Iron

Carbon / Lead / Iron



Lead



Iron / Lead

Event Rates

- MINERνA has been approved for 4.9e20 P.O.T. in the low energy neutrino beam
  - So far, we have received 1.2e20 P.O.T. (24% of total)

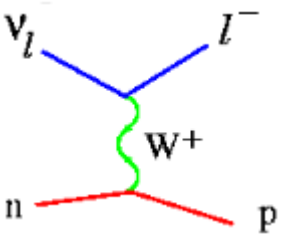
MC

Expected Event Rates for Low Energy Neutrino-tuned beam

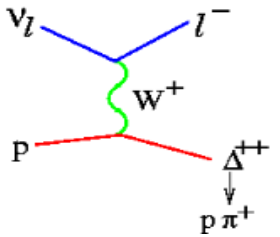
Target	Fiducial Mass	ν_μ CC Events in 1.2e20 P.O.T.
Plastic	6.43 tons	409k
Helium	0.25 tons	16.8k
Carbon	0.17 tons	10.8k
Water	0.39 tons	24.4k
Iron	0.97 tons	64.5k
Lead	0.98 tons	68.4k

Some CC inclusive events:

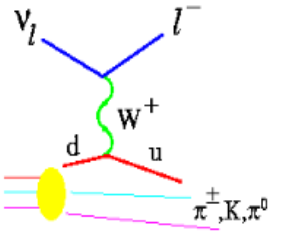
Quasi-elastic



Resonance production



Deep Inelastic Scattering

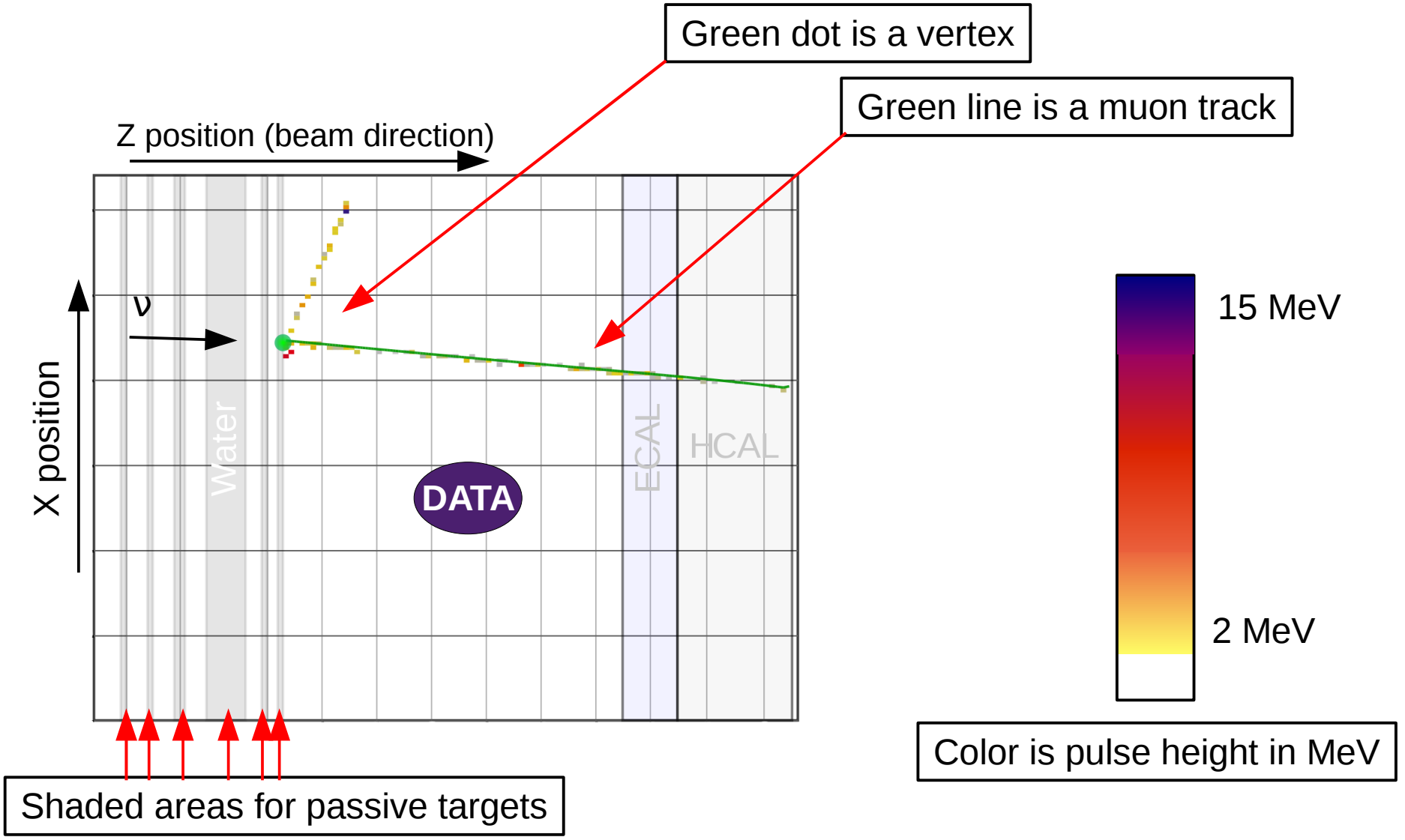


Nuclear Effects with MINERνA

- Designed to measure neutrino-nucleus cross-section in C, Fe, Pb, He and H_2O.
  - Having all targets in the same detector and same beam reduces systematic errors in comparisons.
- Study nuclear effects and the A-dependence in neutrino interactions.
- Status on the analysis to compare charge current inclusive cross sections in plastic, Fe and Pb as function of muon energy.

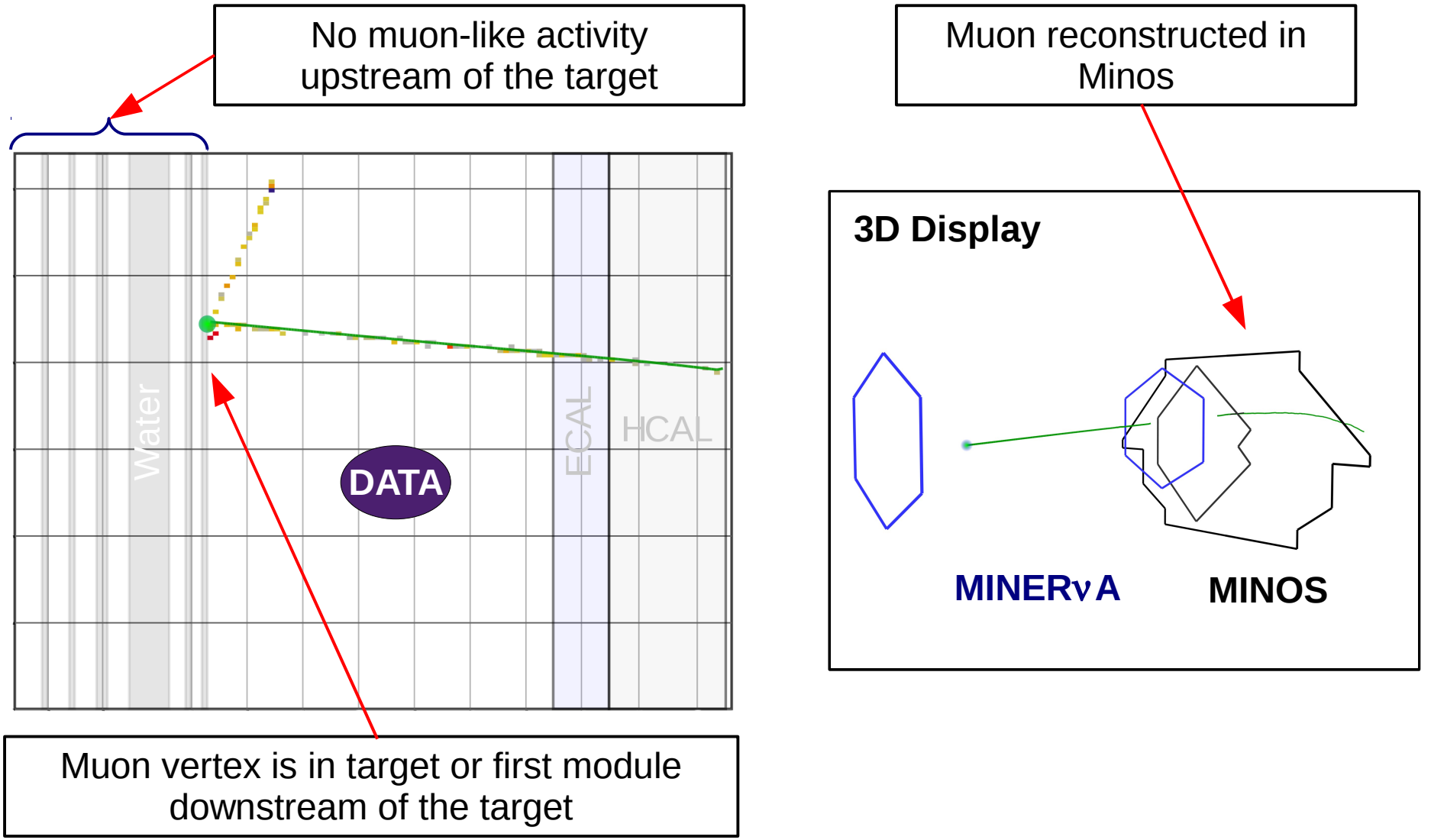
Nuclear Targets in Event Display

CC event candidate from last target



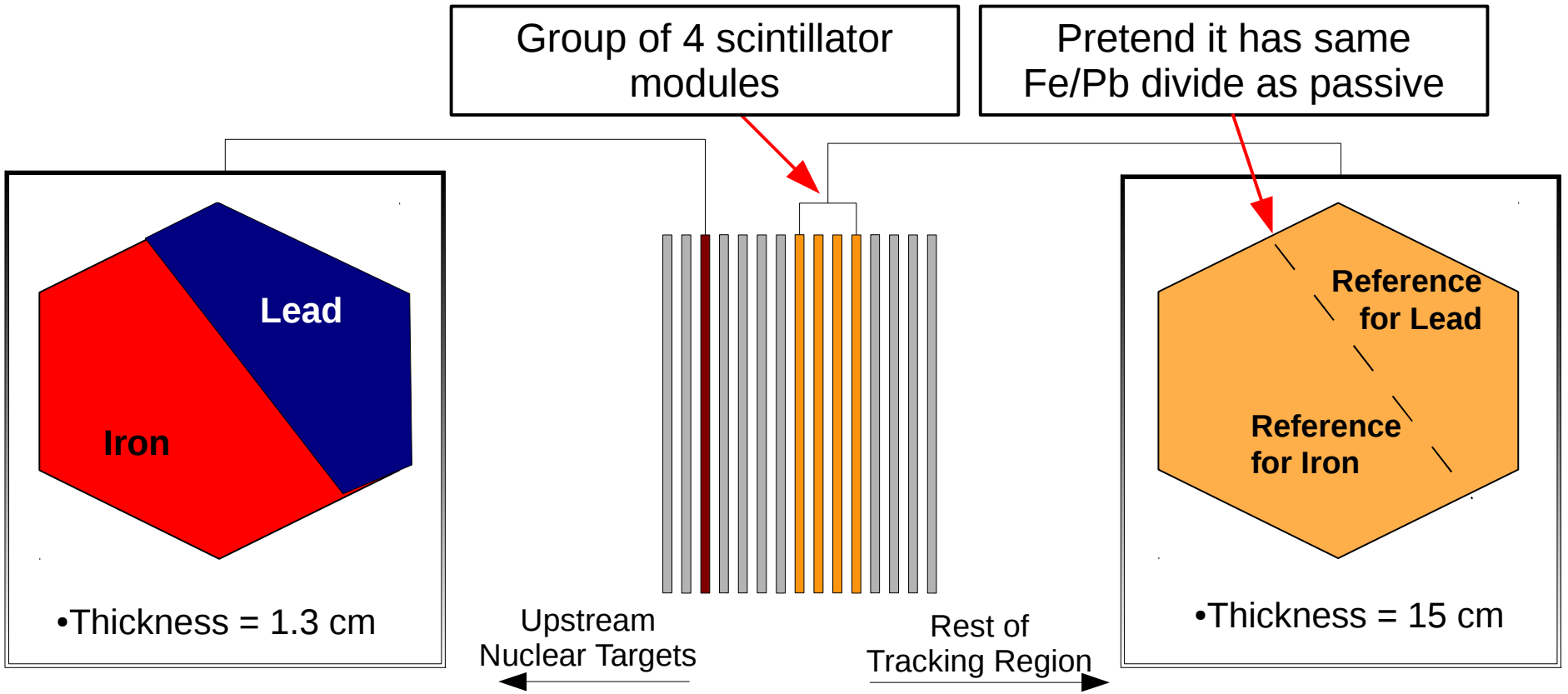
Nuclear Targets Event Selection

CC event candidate from last target



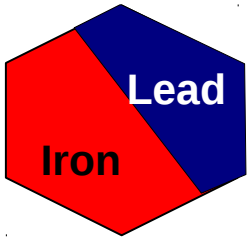
Plastic Reference Target

- All we do for the passive target can be done for a plastic reference target.
  - Compare plastic to Pb and Fe.
  - Minimize systematic errors (efficiency, area, acceptance)



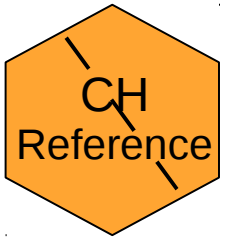
Muon Energy

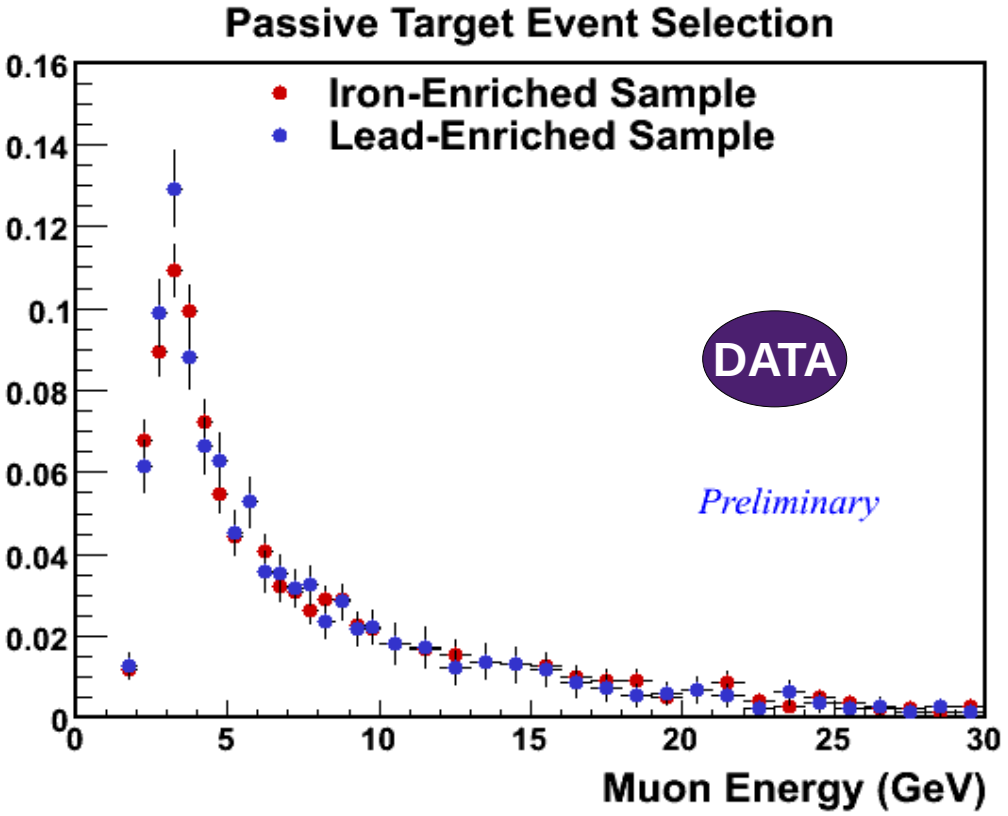
ν_μ CC events

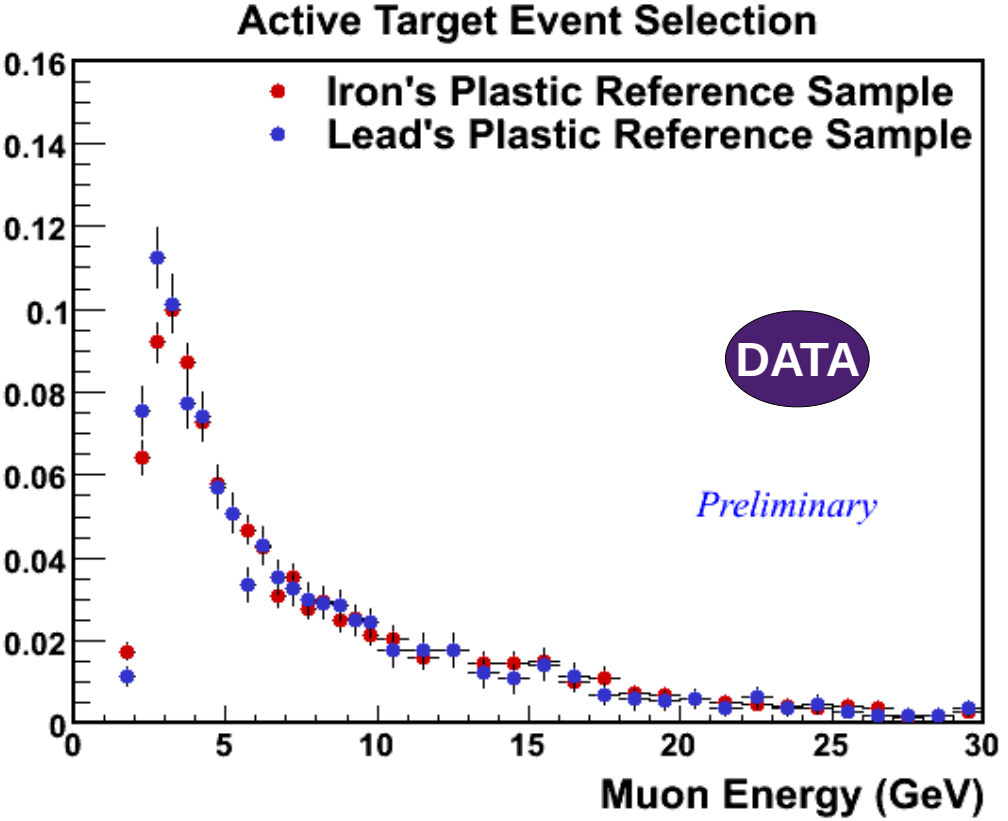


Area-Normalized

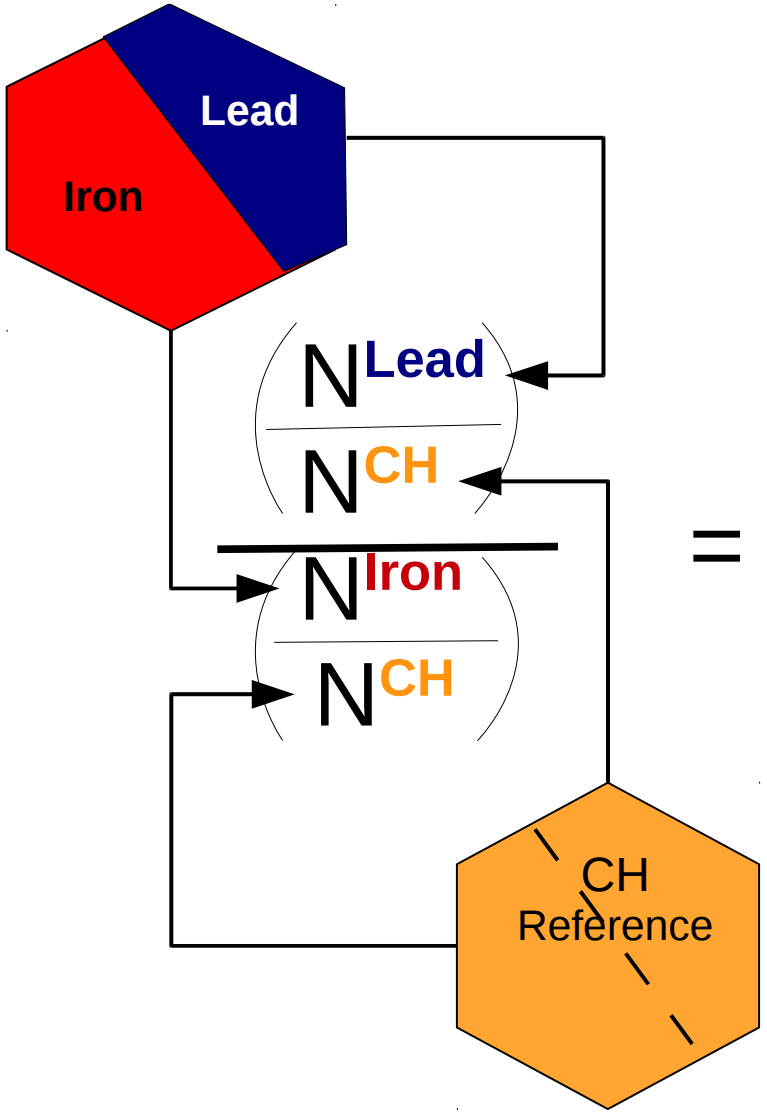
Statistical Error Only







Lead to Iron Ratio



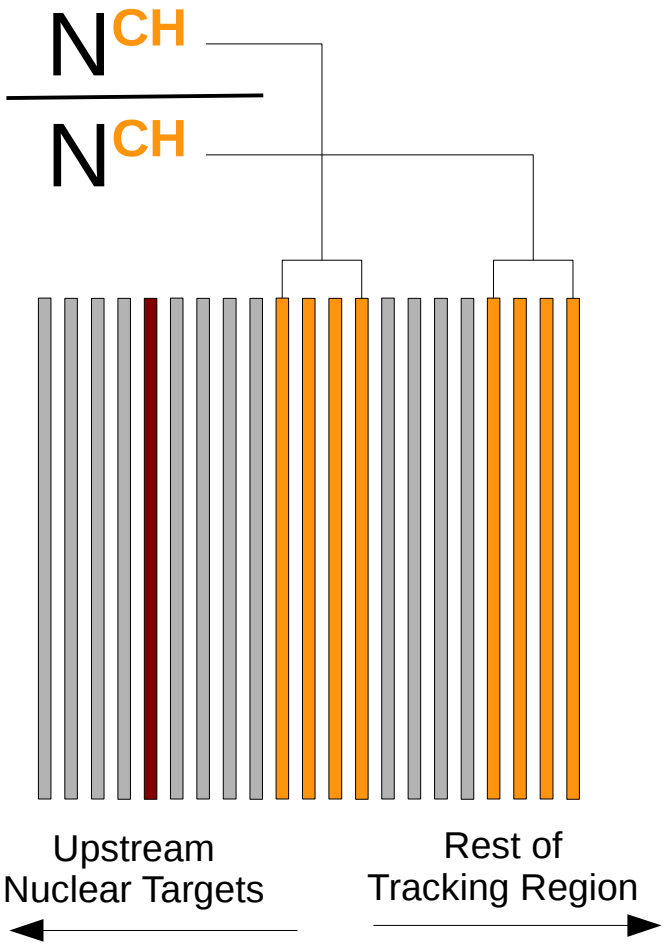
- Ratio removes dependence on neutrino flux.
  - **Lead** and **Iron** see the same beam.

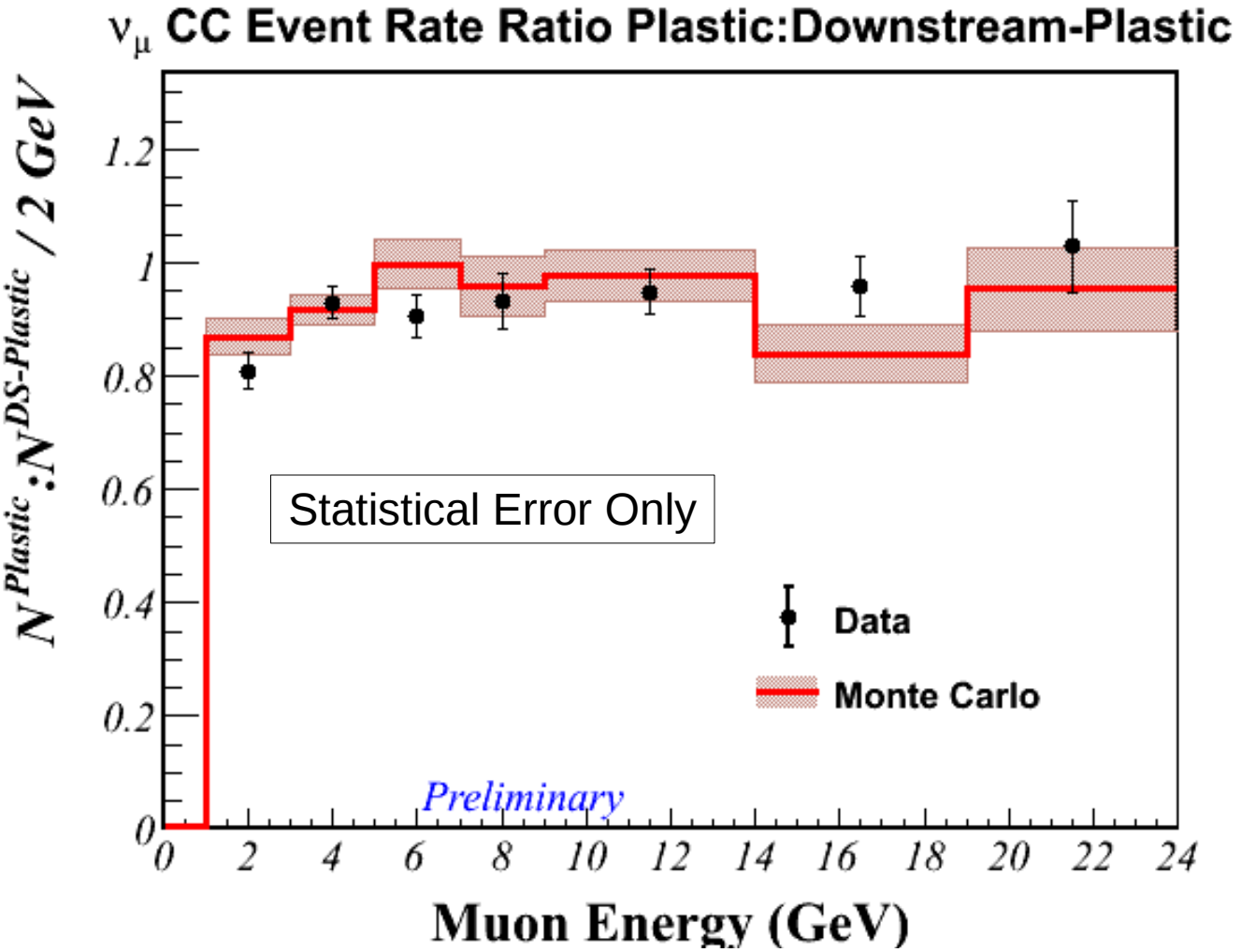
Coming Soon

- Using plastic reference targets minimizes systematic error from different X:Y regions.

Plastic to Plastic Ratio

- Add another reference target downstream to compare plastic with plastic.
- Measure differences in acceptance between this two positions.





Summary

- MINERνA is an experiment in the NuMI beamline aiming to improve neutrino cross section measurements and studying nuclear effects.

- Currently working to produce ratios of CC inclusive cross sections of ν_μ on plastic, lead and iron.

- Stay tuned for new results.

Thanks for listening

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Backups

MINERνA objetives

- Provide more precise charged current quasi-elastic cross sections to oscillation experiments
- Measure *x*-dependence of nuclear effects
  - e.g. F_2 and xF_3
    - Are sea and valence quarks affected differently?
- Contribute to community efforts to extract the dependence of nuclear parton distribution functions on A, *x* and Q^2

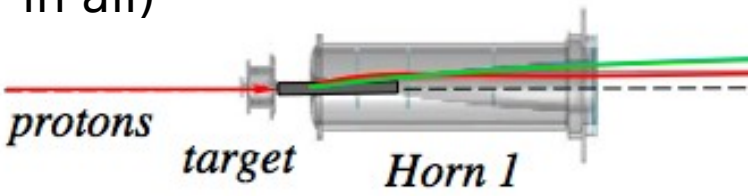
MINERνA objetives

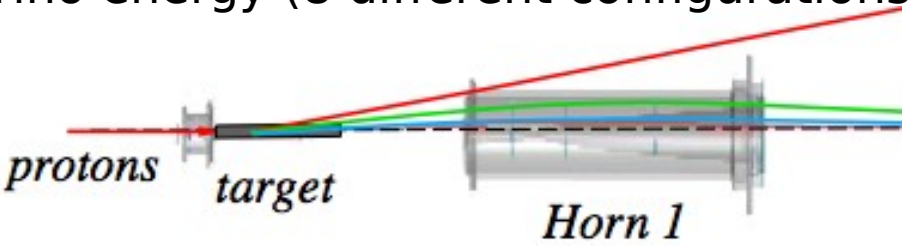
- Measure final state multiplicities as a function of A
  - Investigate pion absorption in the interaction nucleus
  - Observe final state interactions (FSI)
    - Improve models of ν-A interaction
- Measure hadronic energy as a function of A
  - What is the A dependence of observed energy?
  - Also measure unobserved energy emission via neutrons
    - Improves neutrino energy resolution

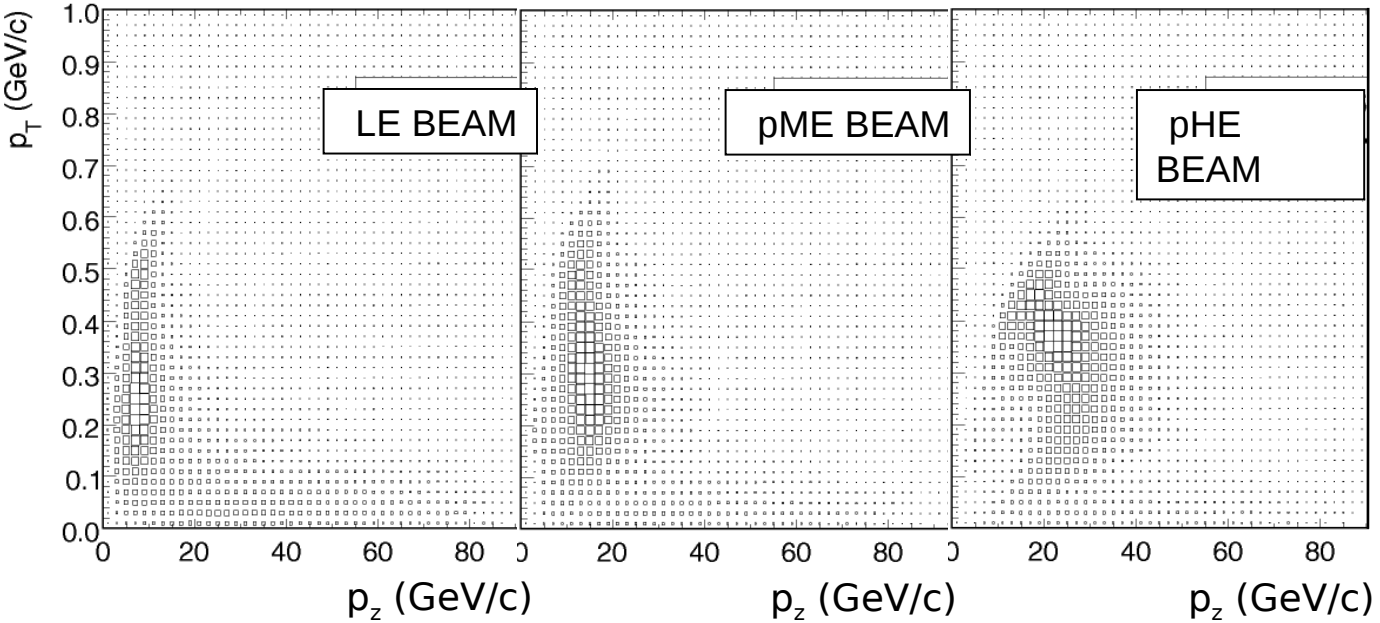
Neutrino flux

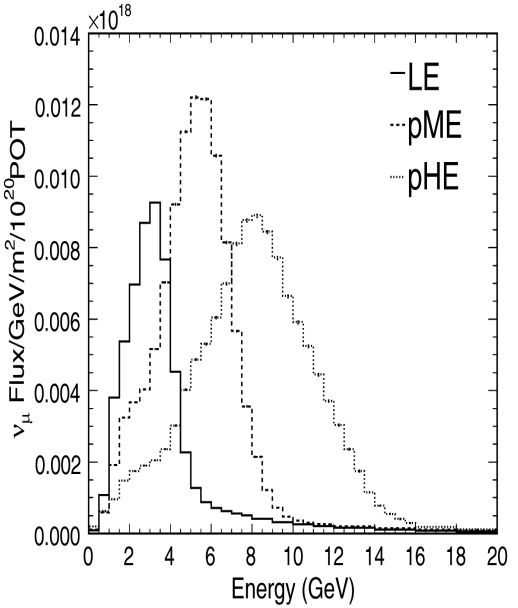
- Understanding the neutrino flux

1. Comparing ν event rates when varying beamline configuration (target z-position and horn current). Each configuration samples different pion kinematics at the same neutrino energy (8 different configurations in all)



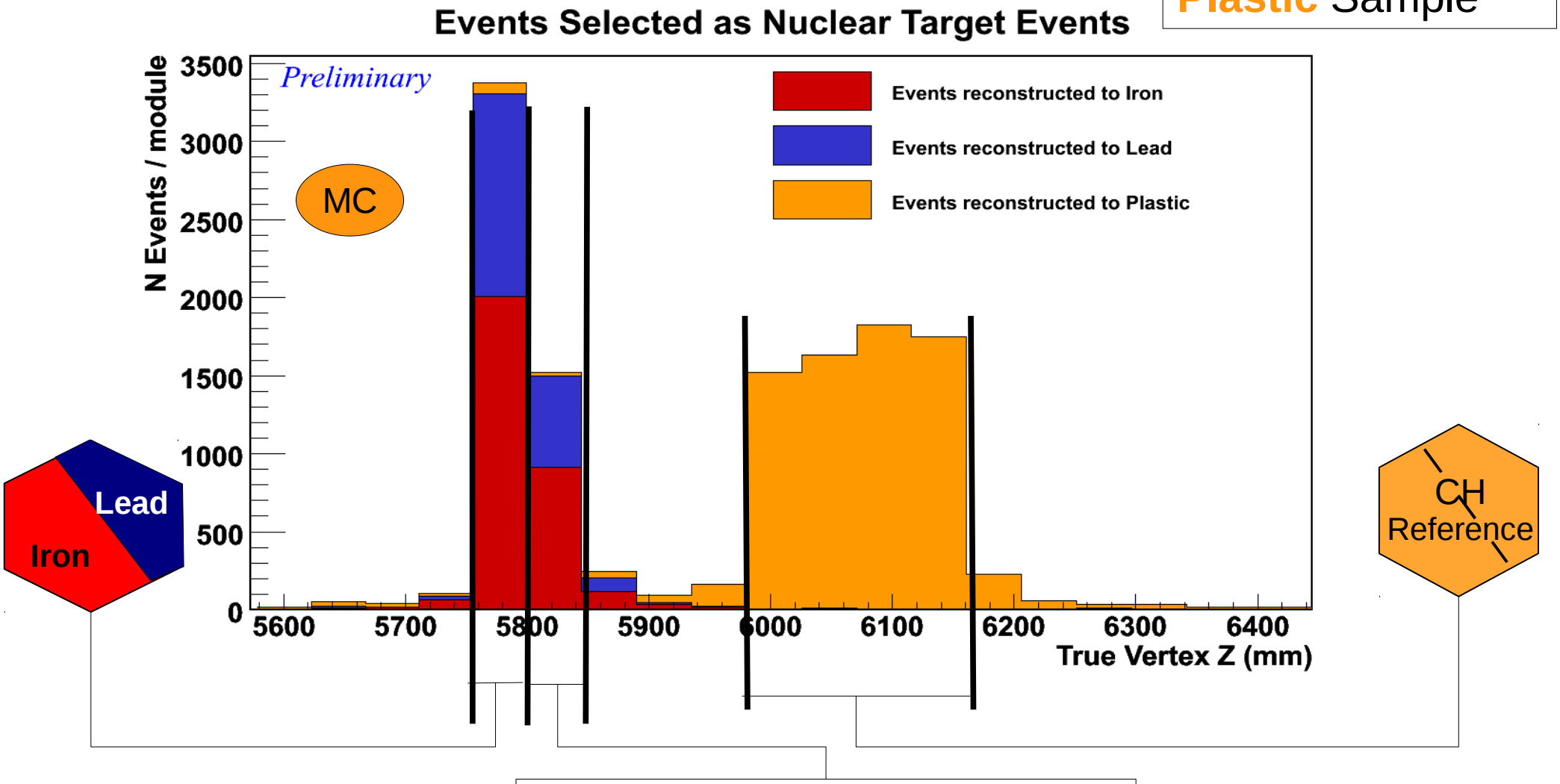






Vertex Z Distribution

Iron-Rich Sample
Lead-Rich Sample
Plastic Sample



- Main contamination is first active module downstream of passive material
  - ALL events in passive target sample have a reconstructed vertex in this module